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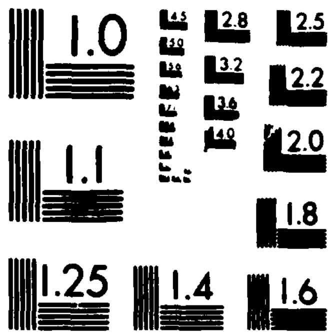

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NRL Report 9035

AD-A179 849

Intelligibility of ICAO Spelling Alphabet Words and Digits Using Severely Degraded Speech Communication Systems.

Part I: Narrowband Digital Speech

ASTRID SCHMIDT-NIELSEN

Communication Systems Engineering Branch
Information Technology Division

March 31, 1987

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The Diagnostic Rhyme Test (DRT) is widely used to evaluate digital voice systems. Would-be users often have no reference frame for interpreting DRT scores in terms of performance measures that they can understand, e.g., how many operational words are correctly understood. This research was aimed at providing a better understanding of the effects of very poor quality speech on human communication performance. It is especially important to determine how successful communications are likely to be when the speech quality is severely degraded. This report compares the recognition of ICAO spelling alphabet words (ALFA, BRAVO, CHARLIE, etc.) with DRT scores for the same conditions. Confusions among the spelling alphabet words are also given. Two types of speech degradation were selected for investigation: narrowband digital speech (the DoD standard linear predictive coding algorithm operating at 2400 bits/s) with varying bit-error rates and analog jamming. The report will be in two parts. Part 1 covers the narrowband digital speech research, and Part 2 will cover the analog jammed speech research.

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INTELLIGIBILITY OF ICAO SPELLING ALPHABET WORDS AND DIGITS USING SEVERELY DEGRADED SPEECH COMMUNICATION SYSTEMS

PART I: NARROWBAND DIGITAL SPEECH

BACKGROUND

There are a number of operational contexts in which voice communication is extremely important, but voice quality can be expected to be moderately to severely degraded. An example is when there is considerable interference, as in a jamming environment. Very low data-rate digital voice systems (800 bit/s and less) are being developed to be more robust under jamming conditions; such systems can also be expected to have somewhat lower intelligibility scores than existing systems at higher data rates.

The evaluation of voice communication systems have been concerned primarily with the intelligibility (and rated acceptability) of the speech signal. Large numbers of intelligibility and quality tests have been carried out with the goal of selecting the best possible system at a given data rate. The Digital Voice Processor Consortium has used the Diagnostic Rhyme Test (DRT) (Voiers, 1977a) and the Diagnostic Acceptability Measure (DAM) (Voiers, 1977b) to evaluate a variety of narrowband and broadband digital voice systems (e.g., Sandy, 1984). These tests are also very useful for evaluating improvements to existing systems (e.g., the LPC Improvement Program conducted at NRL by George Kang). Because of its high reliability and stability over time, the DRT has proved to be a very useful tool for comparing the intelligibility of a variety of speech systems. The Digital Voice Processor Consortium suggests a set of descriptors for various ranges of DRT scores (Table 1). In this context, a DRT score below 70 is generally considered to be "unacceptable," and this is a useful criterion for selecting or developing voice systems.

Table 1 — Descriptors for Interpreting DRT Scores

DRT Score	Descriptive Label
100-95	EXCELLENT
95-90	VERY GOOD
90-85	GOOD
85-80	FAIR
80-75	POOR
75-70	VERY POOR
below 70	UNACCEPTABLE

In actual operational environments, the communication system is already in place, and it is often extremely important to communicate accurately even (or perhaps especially) under adverse conditions such as might occur when there is high interference or jamming. In this case there is no choice as to

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the quality of the communication link; the communicator must work with the existing system even though it might be judged to be "unacceptable" in the laboratory. Standard DRT intelligibility test scores are not at present very informative about user performance in these very poor voice conditions. Even though providing a set of descriptors does help somewhat, many would-be users have no reference frame for interpreting DRT scores in terms of performance measures that they can understand, e.g., how many operational words are correctly understood. Field tests are not a very satisfactory solution because they are very expensive to conduct, and they are also highly context-dependent so that the results tend to vary with changing conditions, making it difficult to generalize any conclusions to other situations.

This research was aimed at providing a better understanding of the effects of poor quality speech on human communication performance. It has been observed that in real-world contexts, people often find a voice system to be acceptable even though it may sound fairly unintelligible to a naive observer who is accustomed to telephone quality. For example, communications between a ground station and a military aircraft may be successful even though the DRT score for the combination of the voice system and aircraft noise is low. When communications occur in the real world, the listener has two kinds of information available to him to help him understand the message: speech information and situational information. Intelligibility tests like the DRT are designed to measure only the speech information. When the speech signal is degraded, the situational information can make it possible to understand an otherwise unintelligible message. In the ground-station-to-aircraft situation, there is a rigid protocol for communication that is known to the users. Furthermore, they use a limited and highly specialized vocabulary consisting of words and phrases that are designed to be easily distinguished. The type of information that is likely to be communicated is also dependent on the nature of the mission and the stage in the sequence of the mission. At any given time, there are only a few alternative messages that are likely to be expected in that context.

As suggested by the previous example, two contextual factors that affect intelligibility are the size of the expected message set and the discriminability of the different messages within the set. Both of these effects are illustrated in an experiment by Miller, Heise, and Lichten (1951). They conducted intelligibility tests using varying numbers of monosyllabic words as the test alternatives; also included were the digits zero to "niner." Figure 1 shows the scores for some of the conditions in this experiment, plotted from the Miller, Heise, and Lichten data after applying a correction for guessing. As the number of response alternatives decreased, a higher percentage of correct responses was obtained, even under severe noise conditions. When the response choices were the ten digits, a set that includes words with varying numbers of syllables, the intelligibility scores were higher than for the set of eight monosyllables and nearly as good as when there were only two choices. A vocabulary consisting of words that vary in the number of syllables and in their stressed vowels is easier to recognize than the same size set of words consisting of monosyllables, especially if the phonetic content is also similar. Under high noise or otherwise degraded conditions, the vowels, especially the stressed vowels, and the syllable patterns of the words become the most important cues for word recognition. The consonants have less energy and are more easily masked by noise interference.

The International Civil Aviation Organization (ICAO) spelling alphabet was developed (Moser, 1959; Moser and Dreher, 1955) so that the words would be highly discriminable from one another, and these words can be used where ordinary language would not be easily understood. Because it is widely used and represents a small but distinctive vocabulary, the ICAO alphabet and the names of the digits for zero to "niner" were chosen for the experiments that are described here. Results using these words can be expected to be similar to those that would be obtained with other small, specialized communication vocabularies.

Two types of speech degradation were selected for investigation: narrowband digital speech with varying bit error rates, and varying degrees of analog radio jamming. The report will be in two parts. Part 1 covers the narrowband digital speech research, and Part 2 will cover the analog jammed speech research.

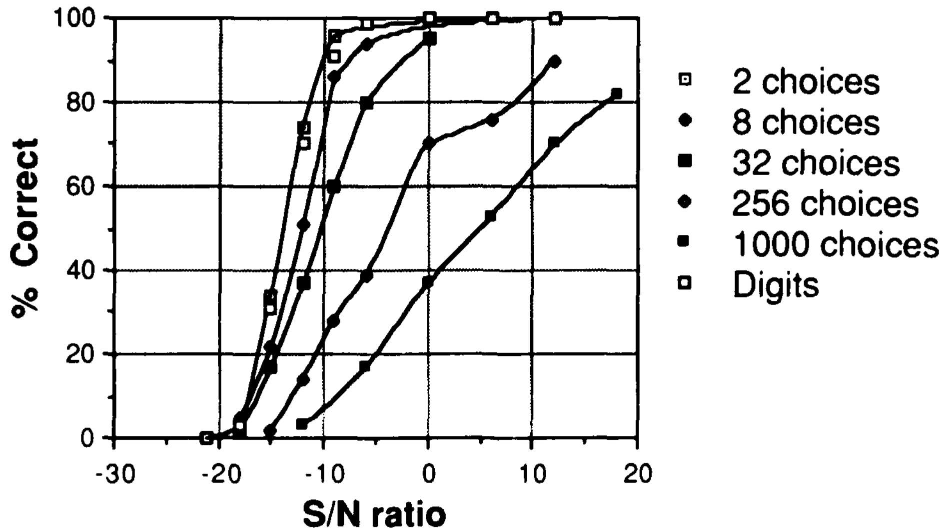

Fig. 1 — Intelligibility scores vary as a function of the size of the response set and the distinctiveness of the responses within the set. (Data adapted from Miller, Heise, and Lichten, 1951.) Corrections for guessing were made before plotting the data. No curve has been drawn for the digits data, which lie very close to the two-choice data. Digits are more distinctive than monosyllables.

INTRODUCTION

For narrowband secure voice communications, a linear predictive coding (LPC) algorithm operating at 2400 bits/s (Tremain, 1982) has been established as the DoD standard (Federal Standard 1015 or MIL-STD-188-113), and has also been adopted by NATO (STANAG 4198). This algorithm is being incorporated in the Navy's Advanced Narrowband Secure Voice Terminal (ANDVT) as well as the new Subscriber Terminal Unit (STU III) voice terminals in production. The Digital Voice Processor Consortium conducted DRT tests of the LPC processor with random bit error rates up to 5% (Sandy, 1984). At the 5% error rate, the DRT score for the LPC processor was 75, which is in the poor to very poor range. Since the purpose here was to investigate performance under severely degraded voice conditions, bit error rates up to 12% were tested. In addition, a very low data rate algorithm operating at 800 bits/s was included. The 800 bit/s rate is based on the standard LPC and employs a pattern matching algorithm (Fransen, 1983). This algorithm is being developed for narrow band antijam applications and could be used at the 2400 bit/s rate with the remaining bits as error protection (Kang and Jewett, 1986).

METHOD

For the voice conditions selected, two sets of scores were obtained. DRT tapes were processed and sent to Dynastat, Inc. for scoring. Listener tests using the spelling alphabet words and the names of the digits were also conducted. The listeners heard random groups of words and they wrote down the letter or digit corresponding to each word.

Speech Materials

For the DRT tests, standard DRT tapes for three male and three female speakers were used. For the alphabet tests, the 26 ICAO spelling alphabet words (ALFA, BRAVO, CHARLIE, DELTA, etc.) and the names of the digits (zero through "niner" were used. There were five speakers: three males and two females. Each speaker first read the 36 words in alphabetical and numerical order and then read four different randomized lists of the words. The randomizations were read in four groups of nine words each with a brief pause after each group. These lists were duplicated, and the groups

of nine test words for the five different speakers were combined into eight test tapes. (To obtain eight tapes, each of the four readings for each speaker was used twice.) Each test tape was constructed so that it consisted of 180 words in 20 groups of nine making up a complete set of letters and numbers for each speaker, but the word groups for the different speakers were intermingled so that the listeners would not be able to guess what words might come next based on what they had heard before. The order of the speakers was balanced across the eight test tapes but appeared random within a tape. Each tape lasted 5.25 min.

Voice Conditions

There were six digitally processed voice conditions as well as the unprocessed, high-quality speech. There were five LPC conditions at bit error rates of 0%, 2%, 5%, 8%, and 12%. The LPC tapes for both the DRT and spelling alphabet tests were generated by processing the tape recorded materials through a low data-rate voice terminal built by TRW. This terminal does not incorporate the LPC enhancements (Kang and Everett, 1982; 1984) that will be included in the ANDVT and STU III equipments, so the newer devices can be expected to perform somewhat better. Random bit errors for the various error conditions were introduced into the bit stream between the analysis and synthesis portions of the processing. The last digital condition was the 800 bit/s pattern matching algorithm based on the standard 2400 bit/s LPC, which was tested for comparison with the LPC with errors. The 800 bit/s speech was obtained using the same TRW terminals, set to operate at the 800 bit/s rate. More recent versions of this algorithm are improved but were not available in real time when these experiments were conducted.

Test Procedure

The testing sessions consisted of a familiarization procedure followed by a practice test, after which the eight test tapes were presented in two groups of four with a 10-15 minute rest between the two halves. For the familiarization, the listeners were told how the spelling alphabet is used and that each letter is represented by a word beginning with the corresponding letter. They then heard each of the five speakers reading the list of spelling alphabet words and the digits in alphabetical and numerical order. For the practice test, they heard a moderately difficult voice condition (LPC speech with 2% bit errors). They were given answer sheets with blanks printed on them in groups of nine and were told to write down the letter or number corresponding to each word that they heard. After the practice, listeners were permitted to check their answers against a list of the correct words and were reminded again of the correspondence between the words and the letters. Some listeners reported that they sometimes had a tendency to substitute letters for numbers (especially where the digit words were slightly different from the everyday pronunciation), and they were asked to be extra careful about this. The test tapes were presented in the same manner as the practice tape with similar answer sheets. The first tape in each group of four was unprocessed speech, so the unprocessed version was heard twice. The six digitally processed speech conditions were presented in different counterbalanced orders for different groups of subjects so that any possible effects of practice or fatigue would be balanced across test conditions. A total of 56 listeners were tested; however, the data from four had to be discarded because the experimenter used the wrong tapes, so there were 52 complete sets of listener data. The subjects were tested in groups of one to four, and the test tapes were played over high-quality stereo headphones using a Nagra IIS tape recorder.

Scoring Procedure

The listeners' responses were typed into a computer for scoring and sorting. The responses were recorded as nearly as possible exactly as written by the listeners. In spite of instructions to write distinctly and to distinguish between digits and letters that might be confused (2-Z, 5-S, 1-I, zero-0), some of the responses were ambiguous. The person who typed in the responses had a list of the correct responses, and when it seemed obvious which response was intended, this was used. That is FIFE and SIERRA do not sound at all alike, so when it was not clear whether "S" or "5" was written, the correct answer would be assumed; however, where a letter was written for a number

(e.g., F for FIFE), the actual response was recorded, even though one might guess that the word was actually heard correctly. The reader who wishes to make adjustments for this type of error, which probably slightly inflates the overall error rates, can consult the confusion matrices given in the appendix of this report to find the number of times "T" was given for TREE, "N" for NINER, and so on. In the highest error conditions, many responses were skipped. In a few cases where it was obvious that a series of several correct responses was merely displaced by one line, the correct responses were recorded, but a single response with blanks before and after it was always recorded in its given position, even if it seemed to be displaced, to avoid guessing errors.

RESULTS

Table 2 shows the percentage of correct responses on the alphabet word task and on the DRT test for the various speech conditions. As expected, the highly discriminable spelling alphabet words were more intelligible under the degraded digital voice conditions than were the rhyming DRT words. However, at the highest bit error rates, the intelligibility of the alphabet words fell off more rapidly. At the 12% error rate, only slightly more than one-half the words were correctly identified, and the alphabet word score was nearly as low as the DRT score. The Digital Voice Processor Consortium reported on tests of the DoD standard LPC processor (Sandy, 1984) with random bit errors at 0%, 0.5%, 1%, 2%, and 5%. For the conditions that were the same, the scores reported here are very similar to the consortium results, although the present scores were about one percentage point lower than those obtained in the consortium tests. This difference can probably be attributed to minor differences in the implementation of the LPC algorithm in the voice processors that were used for the different tests.

Table 2 — ICAO Spelling Alphabet Word Scores and DRT Scores for the Degraded Digital Speech Conditions

Speech Condition	DRT Score	ICAO Alphabet Score
Unprocessed	97.6	99.0
LPC 0% errors	86.0	98.0
LPC 2% errors	81.9	96.2
LPC 5% errors	75.4	91.3
LPC 8% errors	65.6	80.0
LPC 12% errors	52.3	54.1
800 bit/s system	77.4	95.4

Figure 2 shows the effect of bit errors on the ICAO spelling alphabet words and on DRT scores, and Fig. 3 shows the relationship between DRT scores and alphabet word scores. The curves that are shown are the best fitting line for DRT scores and the best fitting second-order polynomial for the alphabet words; a third-order polynomial* can be used to describe the relationship between DRT scores and spelling alphabet word scores within the range tested here. The prediction equations are:

DRT from bit error rate: $Y = 87.474 - 2.821\,X$

ICAO words from bit error rate: $Y = 97.288 + 0.912\,X - 0.363\,X^2$

ICAO words from DRT: $Y = -296.2 + 11.82\,X - 0.118\,X^2 + 0.000393\,X^3$

*A second-order polynomial "fits" the data just as well, but would predict a drop in the intelligibility of spelling alphabet words for the highest DRT scores.

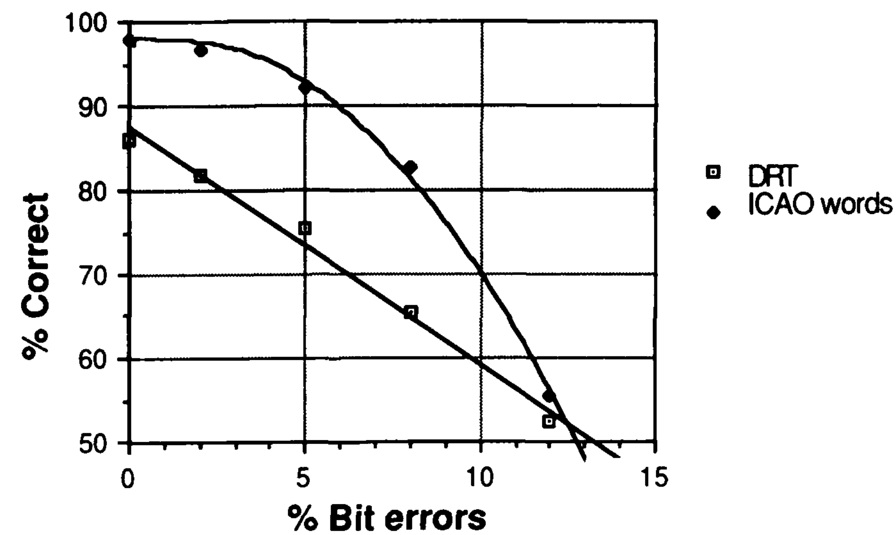

Fig. 2 — DRT scores and scores for the ICAO spelling alphabet and digits for the standard LPC algorithm at 2400 bits/s as a function of random bit error rate

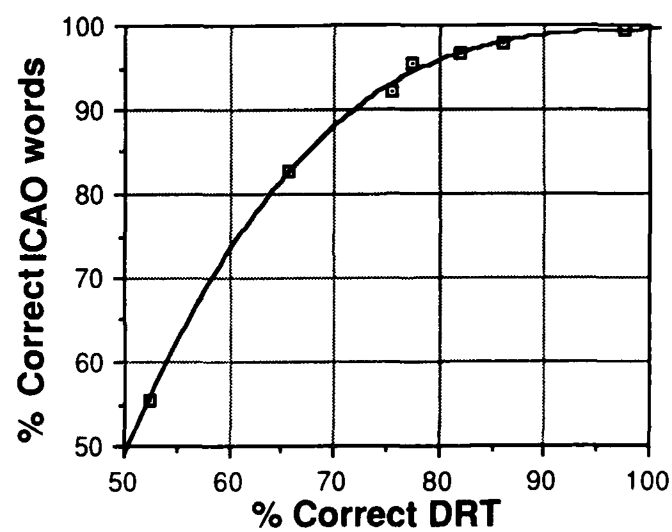

Fig. 3 — Scores for the ICAO spelling alphabet and digits as a function of DRT score. Scores should not be extrapolated beyond the range of the data reported here.

These equations should be considered to be purely descriptive. No underlying theoretical relationship is implied, and the equations should not be used for extrapolation. This is not a serious limitation since intelligibility cannot exceed 100%, and a voice system for which only about one-half of the words can be understood is for practical purposes unusable.

The 36-word vocabulary consisting of the spelling alphabet words and the ten digits behaved similarly to the small response set tests in the Miller et al. (1951) experiments, whereas the DRT, which has two highly similar rhyming response alternatives for each item, behaved very similarly to the large response set tests. By manipulating the discriminability of the items, the usual effect of size of the response set can be reversed. These data still conform to the general principle that easy discriminations, whether due to restricting the response set or to increasing the discriminability of the responses, remain intelligible longer than difficult ones. This experiment as well as the results of

Miller et al. suggest that the easiest discriminations are highly intelligible under increasingly severe degradations up to the point where it becomes practically impossible to understand any speech at all, and then intelligibility rapidly degenerates. More difficult discriminations begin to show some losses even under mild degradations and tend to fall off gradually with increasing speech degradation. The Consortium test results (for the range from 0% to 5% bit errors) also showed a linear relationship between bit error rate and DRT scores. Moser and Dreher (1955) in reporting on the development of the ICAO alphabet indicated a curvilinear relationship between S/N and the intelligibility of spelling alphabet words. However, the difference in difficulty between the rhyme test task and the word task found here differs from results reported by Webster (1972), who states that ". . . Rhyme test scores are generally equivalent to scores on Brevity Code words (including digits and ICAO phonetic spelling words)." These different results may be due to differences in the test methods that were used. For making comparisons between different intelligibility tasks, it is important to understand the task variables that contribute to the ease or difficulty of the discrimination. With small sets of response alternatives, it is also essential to make the appropriate corrections for guessing. Voiers (1983) showed that the DRT and the Modified Rhyme test (MRT) (House et al., 1965) are highly correlated, and the scores tend to be similar when the appropriate corrections for guessing are made. Without such corrections, the lowest score for a two-choice test would be 50%, but it would be 20% for a five-choice test. Clearly, with large numbers of choices, the effect of guessing becomes insignificant. Figure 3 relates DRT scores specifically to spelling alphabet words and digits. A similar relationship can only be expected for other pairs of tasks if the task characteristics are similar (i.e., other fixed choice rhyme tests such as the MRT and other small, distinctive vocabularies).

It can be seen from Fig. 3 that for DRT scores down to about 75, over 90% of spelling alphabet words are correctly recognized, and at a DRT score of 65, more than 80% of the words are still recognized correctly. Experienced communicators who are highly familiar with the vocabulary can be expected to perform even better than these tests indicate. In constrained contexts with standard phrases and a distinctive vocabulary, communication can be good even when the DRT score for the voice system is as low as 75, a score that would be considered to be "poor" to "very poor." Even with a system that has a DRT score below the "unacceptable" level, some communication should be possible, but it would be essential to confirm all information, and some errors as well as slower communication might be expected. When the DRT score falls below 65, communication can be expected to be highly unreliable at best.

Speaker Differences

The speakers used in these tests were to some extent selected for their different voice characteristics. Of the male speakers, DC was known from past experience to have a voice that performed particularly well with the LPC processor, whereas HM had a voice known to be difficult over LPC, and CT had a voice at the higher end of the pitch range for male voices. Of the two female voices, VV had a higher pitch than AS. (LPC tends to perform more poorly with higher pitched voices.) As was to be expected, there were large individual differences among speakers in the number of alphabet words that were recognized, and speaker differences increased with increasing bit-error rates. Figure 4 shows individual speaker scores for the bit-error conditions. This gives some suggestion of the range of scores that can be expected with different speakers. If the scores for HM (the known poor speaker over LPC) are excluded, the usual finding that female voices perform more poorly over LPC are excluded, the usual finding that female voices perform more poorly over LPC than male voices is also confirmed. Since the speakers for the alphabet word tests were not the standard DRT speakers, it is difficult to make direct comparisons with the DRT results. There were also speaker differences and sex differences in the DRT scores. Figure 5 shows the expected difference between male and female speakers for the DRT scores.

Word and Phoneme Confusions

The words that are most likely to be confused with one another are quite different with the digital degradations used here than the types of confusions that were found with noise degradation when

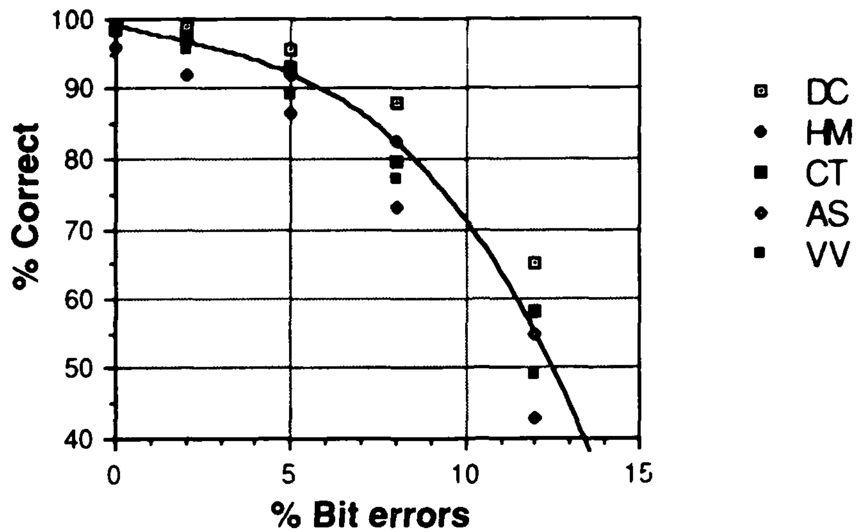

Fig. 4 — Speaker differences for the ICAO spelling alphabet and digits for the standard LPC algorithm as a function of random bit error rate. Speaker differences increase as the speech becomes more degraded.

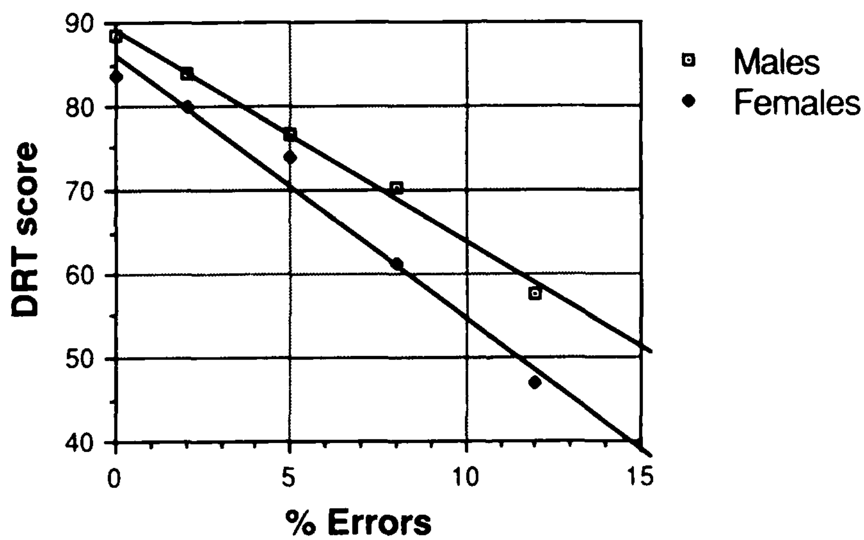

Fig. 5 — DRT scores for male and female speakers for the standard LPC algorithm at 2400 bits/s as a function of random bit error rate. Scores for female speakers are lower and decrease more rapidly than for male speakers.

the research to select the currently used ICAO alphabet was being conducted (Moser and Dreher, 1955; Moser, 1959). Full confusion matrices for the spelling alphabet words and the names of the digits are given in the appendix for each of the conditions tested. Since the confusions tended to be similar across bit-error conditions, changing primarily in number, a confusion matrix combining the data for the three highest bit-error conditions (5%, 8%, and 12%) is included as a summary of the most frequent confusions. Table 3 lists the most frequently confused words, those that were most omitted, and the words with the most total errors—confusions and omissions.

For comparison with the types of confusions that are made in noise, some of the most frequent confusions and omissions from Moser (1959) are shown in Table 4. Since different combinations of words were being tested, and all of the tests that were reported by Moser (1959) have some words

Table 3 — Most Frequently Confused Words, Most Frequently Omitted Words, and Words with the Most Total Errors for LPC Speech with High Bit-Error Rates (Averaged over the 5%, 8%, and 12% Conditions)

CONFUSIONS		Percent of responses	OMISSIONS		TOTAL ERRORS	
Spoken	Heard as		Word	Percent of responses	Word	Percent of responses
PAPA	ALFA	21.9	ECHO	26.6	PAPA	56.0
DELTA	ALFA	14.2	GOLF	25.6	ECHO	44.3
INDIA	JULIETT	10.4	MIKE	20.3	MIKE	42.8
TWO	ZERO	8.5	QUEBEC	19.4	GOLF	42.1
KILO	ZERO	6.9	BRAVO	19.2	EIGHT	32.8
EIGHT	SIX	6.9	YANKEE	17.4	BRAVO	32.6
MIKE	FIFE	6.7	TANGO	17.1	TANGO	32.3
ZERO	ZULU	5.6	EIGHT	15.8	INDIA	31.5
OSCAR	FOXTROT	5.1	VICTOR	14.9	QUEBEC	31.5
ALFA	DELTA	5.0	HOTEL	14.4	DELTA	30.0

Table 4 — Some Frequent Confusions and Omissions Obtained by Moser (1959) in Tests of ICAO Words in Noise

CONFUSIONS		OMISSIONS
Spoken	Heard	
FOXTROT	OSCAR	ECHO
ECHO	X-RAY	GOLF
X-RAY	OSCAR	JULIETT
ZULU	JULIETT	QUEBEC
JULIETT	ZULU	TANGO
ECHO	HOTEL	VICTOR
HOTEL	ECHO	BRAVO

that are different from those in the present ICAO alphabet (e.g., FOOTBALL, NECTAR, and ZEBRA in one version), it is difficult to make precise comparisons between their results and the present data. Only words that do overlap with the present ICAO alphabet are included in Table 3. Total errors are not shown because the composition of the list as a whole influences the nature of the error patterns. Although the words that were confused with one another in noise are quite different from the confusions with the digital degradations, the words that were omitted (i.e., not understood at all) were quite similar in the two cases. The most frequent confusion for the degraded digital speech was PAPA-ALFA, and these words were almost never confused in the Moser studies. The reverse confusion ALFA-PAPA was also very rare for the digital speech. There were a number of highly asymmetrical confusions for the digital degradations, whereas the general pattern of confusions tended to be considerably more symmetrical for noise degradation. This suggests that the LPC degradations tend to eliminate the speech cues that are needed to make certain distinctions; specifically, the abrupt onsets that cue the stop consonants (p, t, k, b, d, g) are blurred by the LPC with bit errors, and the sounds are heard as continuants instead (f, z, th, v, etc.). This effect can also be seen in the frequent KILO to ZERO confusion. The LPC enhancements (Kang and Everett, 1984) include a window placement strategy that greatly improves the reproduction of these sounds, and some of the confusions reported here may be less serious for the newer processors that include the LPC enhancements. The confusions that were based on vowel similarity and syllable patterns were more symmetrical, for example MIKE and FIFE or ALFA and DELTA, but even these showed more errors in the direction of substituting sustained sounds for stops.

Figure 6 shows the effect of bit errors on DRT feature scores. The graveness and sustention features had the lowest overall scores in all conditions. Sustention is the feature that allows us to distinguish between p and f, b and v, etc. Graveness allows us to distinguish between sounds like b and d or f and th, among others. The nasality feature (m/b, n/d) scored high at the low bit-error rates but fell off more than others with increased bit error rates. Voiers (1983) also found graveness and sustention to be the most vulnerable under noise degradation, but nasality remained robust in noise.

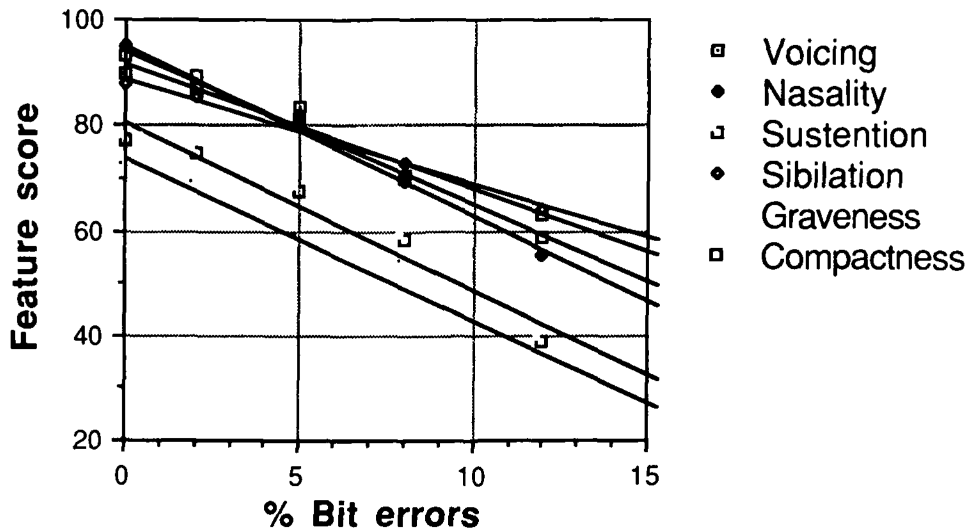

Fig. 6 — DRT feature scores for the standard LPC algorithm at 2400 bits/s as a function of random bit error rate. The graveness and sustention features are the most vulnerable to degradation under these conditions.

CONCLUSIONS

It has been frequently observed that different measures of speech intelligibility are highly correlated with one another (e.g., Montague, 1960; Webster, 1972; Voiers, 1983). Thus once the relationship between two measures has been established, it becomes possible to predict one from the other. In this case the highly reliable and widely used DRT scores can be used to predict the performance of digital voice systems using small, distinctive vocabularies such as the ICAO spelling alphabet and the digits. The relationships shown in Fig. 3 can be used to interpret DRT scores for other, similar digital voice systems. This should help to make the DRT scores more meaningful to users of the voice systems. Small changes in DRT scores at the high end of the scale are most important for ordinary conversational speech where a varied vocabulary is to be expected or for transmitting highly specialized information where many words may sound similar. With distinctive military vocabularies, word intelligibility can be expected to remain high even when DRT scores fall into the poor range, but once the DRT scores fall below about 75, the intelligibility can be expected to fall off rapidly, and at scores below 50, less than one-half the words will also be understood.

Given the negligible losses in spelling alphabet and digit intelligibility for the LPC system that was used in the present tests, the ANDVT and STU III equipments incorporating the LPC enhancements, and with DRT scores that are several points higher, can be expected to be virtually error free on this type of vocabulary. Similarly, the more recent 800 bit/s algorithm using line spectrum frequencies (Kang and Fransen, 1985) also has a better DRT score than the system tested here, and over 96% of such words can be expected to be correctly understood, 98% with good speakers. Even under relatively severe degradation due to random bit errors, the recognition of distinctive vocabularies can be expected to remain quite good. The more degraded the voice system becomes, the more important individual speaker characteristics will be. If conditions are expected to be severely

degraded, it becomes important to use communicators whose voices perform well over LPC systems. At the 8% bit-error rate, the very good speaker, DC, scored 87% correct, whereas the poor speaker, HM, scored only 73% in the same condition. Since LPC systems are expected to be in widespread use, a useful research area will be an investigation of the voice traits that characterize "good" and "poor" LPC speakers.

The confusion matrices in the appendix can be used to pinpoint specific word pairs that are the most likely to lead to difficulties at high bit-error rates. For specific situations where it is essential to communicate certain information under very poor conditions, it may be advantageous to select code words or names from those items that are the least likely to be confused or missed.

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Appendix

CONFUSION MATRICES

These matrices are for the ICAO spelling alphabet words and the digits using unprocessed speech as well as for six digital speech conditions.

1. Unprocessed speech, 99.0% correct.
2. LPC with 0% bit errors, 98.0% correct.
3. LPC with 2% bit errors, 96.2% correct.
4. LPC with 5% bit errors, 91.3% correct.
5. LPC with 8% bit errors, 80.0% correct.
6. LPC with 12% bit errors, 54.1% correct.
7. LPC with 5%, 8%, and 12% bit errors combined.
8. 800 bit/s pattern matching algorithm, 95.4% correct.

The total number of possible responses for each spoken word was 260 for each matrix except condition 7, the combined matrix, for which there were 780 total responses.

CONFUSION MATRIX FOR CONDITION UNPROCESSED (LIST 5), ALL SPEAKERS

RESPONSE

Spoken	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	0	1	2	3	4	5	6	7	8	9	NONE	
Alfa	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	A.
Bravo	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	B.
Charlie	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	C.
Delta	0	0	0	259	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	D.
Echo	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	E.
Foxtrot	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	F.
Golf	0	0	0	0	0	0	259	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	G.
Hotel	0	0	0	0	0	0	0	258	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	H.
India	0	0	0	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	I.
Juliett	0	0	0	0	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	J.
Kilo	0	0	0	0	0	0	0	0	0	0	258	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	K.
Lima	0	0	0	0	0	0	0	0	0	0	0	259	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	L.
Mike	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	M.
November	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	N.
Oscar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	O.
Papa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	P.
Quebec	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	258	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Q.
Romeo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	259	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	R.
Sierra	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	257	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	S.
Tango	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	259	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	T.
Uniform	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	U.
Victor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	259	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	V.
Whiskey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	W.
Xray	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	259	0	0	0	0	0	0	0	0	0	0	0	0	0	X.
Yankee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	253	0	0	0	0	0	0	0	0	0	0	0	0	Y.
Zulu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	258	0	0	1	0	0	0	0	0	0	0	1	Z.
Zero	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	8	251	0	0	0	0	0	0	0	0	0	0	0.
One	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	1.
Two	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	258	0	0	0	0	0	0	0	1	2.
Tree	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	253	0	0	1	0	0	0	0	3.
Fower	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	258	0	0	0	0	0	0	4.
Fife	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	259	0	0	0	0	0	5.
Six	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	259	0	0	0	1	6.
Seven	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	7.
Eight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	8.
Niner	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	256	2	9.

CONFUSION MATRIX FOR CONDITION LPC 0% ERRORS, ALL SPEAKERS

RESPONSE

Spoken	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	0	1	2	3	4	5	6	7	8	9	NONE	
Alfa	258	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	A.
Bravo	0	256	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	B.
Charlie	0	0	258	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	C.
Delta	0	0	0	258	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	D.
Echo	0	1	0	0	249	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	8	E.
Foxtrot	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	F.
Golf	1	0	0	0	0	0	251	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	4	G.
Hotel	0	0	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	H.
India	0	1	0	0	0	0	0	0	253	4	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	I.
Juliett	0	0	0	0	0	0	0	0	0	259	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	J.
Kilo	0	0	0	0	0	0	0	0	0	0	256	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	K.
Lima	0	0	0	0	0	0	0	0	0	0	0	256	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	2	L.
Mike	0	0	0	0	0	0	0	0	0	0	1	0	256	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	M.
November	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	N.
Oscar	1	0	0	0	0	0	0	0	0	0	0	0	0	0	254	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	O.
Papa	32	0	0	1	0	1	0	0	0	0	0	0	0	0	0	223	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	P.
Quebec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	259	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	Q.
Romeo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	258	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	R.
Sierra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	S.
Tango	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	257	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	T.
Uniform	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	257	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	U.
Victor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	258	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	V.
Whiskey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	259	0	0	0	0	0	0	0	0	0	0	0	0	0	1	W.
Xray	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	254	0	1	0	0	0	0	0	0	0	0	0	0	0	X.
Yankee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	257	0	0	0	0	0	0	0	0	0	0	0	3	Y.
Zulu	0	1	0	0	0	0	0	0	0	2	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	251	0	0	0	0	0	0	0	0	0	0	2	Z.
Zero	0	0	0	0	0	0	0	0	0	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	16	238	0	0	0	0	0	0	0	0	0	1	0.
One	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	259	0	0	0	0	0	0	0	0	1	1.
Two	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	1	250	1	0	0	0	0	0	0	3	2.
Tree	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	252	0	0	0	0	0	0	0	3.
Fower	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	255	0	0	0	0	0	3	4.
Fife	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	254	0	0	0	0	3	5.
Six	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	0	6.
Seven	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	259	0	0	1	7.
Eight	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	253	0	3	8.
Niner	0	0	0	0	0	0	0	0	0	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	253	0	9.

CONFUSION MATRIX FOR CONDITION LPC 8% ERRORS, ALL SPEAKERS

RESPONSE

Spoken	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	0	1	2	3	4	5	6	7	8	9	NONE	
Alfa	224	1	0	14	0	4	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	11	A.
Bravo	5	213	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	B.
Charlie	0	0	219	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	2	0	0	0	0	0	0	1	2	0	7	0	3	21	C.
Delta	44	1	0	176	0	1	1	5	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	3	0	25	D.
Echo	2	1	1	5	142	2	0	6	0	0	2	3	1	0	0	3	1	0	1	6	1	12	0	1	0	0	1	0	2	0	0	0	1	1	0	0	65	E.
Foxtrot	1	0	0	0	0	254	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	F.
Golf	13	2	3	0	1	0	144	2	0	0	1	2	1	1	0	3	0	5	0	0	0	0	1	0	0	3	2	0	1	1	1	14	0	0	2	0	57	G.
Hotel	0	0	0	0	0	0	1	221	0	0	1	0	0	0	0	0	0	6	0	0	0	0	0	0	0	3	0	0	1	0	0	0	0	0	1	0	26	H.
India	0	0	0	0	0	0	0	0	197	35	1	1	0	0	0	0	0	1	0	0	1	0	0	0	0	4	0	0	0	0	0	0	0	0	0	1	19	I.
Juliett	0	0	0	1	0	0	1	0	3	236	0	1	0	0	1	0	1	2	2	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	10	J.
Kilo	0	0	0	0	0	0	0	0	0	0	189	5	0	0	0	0	2	1	1	1	0	1	0	0	0	13	21	0	0	0	1	1	0	6	0	0	18	K.
Lima	0	0	0	0	0	0	0	0	1	0	1	214	0	0	2	0	0	1	0	0	0	1	0	0	1	4	10	1	1	0	1	0	0	0	0	1	21	L.
Mike	0	0	0	0	0	2	0	0	2	1	0	2	166	1	1	0	1	0	0	0	0	0	0	0	1	0	1	2	0	2	0	13	2	1	3	13	46	M.
November	0	0	0	0	0	1	0	0	0	0	0	4	0	225	0	0	3	0	1	0	[illegible]	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	23	N.
Oscar	6	0	0	1	0	17	0	2	0	0	0	0	1	0	216	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	14	O.
Papa	67	3	0	10	1	10	0	6	0	0	0	0	0	0	1	108	0	0	0	1	0	2	0	0	0	0	0	1	0	0	1	2	0	0	1	0	46	P.
Quebec	4	0	0	0	0	0	0	0	1	0	2	1	0	0	0	1	199	0	2	0	1	0	0	1	0	0	1	1	0	1	0	0	1	9	0	0	35	Q.
Romeo	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	246	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	9	R.
Sierra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	240	0	0	0	0	0	0	1	5	0	1	1	0	0	0	0	0	0	12	S.
Tango	0	0	0	2	2	0	1	1	2	5	8	2	0	0	0	0	0	4	1	180	0	0	0	0	0	6	4	0	0	0	0	1	0	2	0	1	38	T.
Uniform	0	1	0	0	0	0	1	0	0	0	0	2	0	0	0	0	1	0	0	1	229	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	13	U.
Victor	0	0	0	1	0	0	0	1	1	0	0	1	0	1	2	0	0	1	0	0	0	194	1	1	1	4	0	0	0	1	0	0	1	0	0	0	49	V.
Whiskey	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	236	2	1	0	0	0	0	2	0	0	1	0	0	0	14	W.
Xray	0	0	0	0	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	235	0	0	0	0	0	0	0	0	2	0	0	0	19	X.
Yankee	0	0	1	0	1	0	0	0	2	0	0	0	0	3	0	0	0	0	1	0	1	0	2	1	213	0	0	1	0	0	0	0	0	0	1	0	33	Y.
Zulu	0	0	1	0	0	0	0	0	0	1	5	7	0	0	0	0	0	4	2	1	2	1	0	0	0	209	10	1	1	0	0	0	0	0	0	0	15	Z.
Zero	0	0	0	0	0	0	0	0	1	2	4	0	0	0	0	0	0	0	14	0	0	0	0	0	0	21	203	0	0	0	0	0	0	4	0	0	11	0.
One	0	0	0	0	0	0	0	0	2	0	0	0	1	7	0	1	0	0	0	0	0	0	0	0	0	4	2	[illegible]	0	1	1	2	0	2	0	8	31	1.
Two	0	0	0	0	0	0	0	0	0	0	[illegible]	0	0	0	0	0	1	0	0	0	0	0	0	0	0	23	0	1	205	0	0	1	0	2	0	0	24	2.
Tree	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	2	215	0	2	1	0	13	1	16	3.
Fower	0	0	0	0	0	0	[illegible]	0	0	0	0	[illegible]	0	0	0	1	0	0	0	0	0	0	0	0	0	6	0	0	0	0	237	1	0	0	1	0	15	4.
Fife	0	3	1	0	0	6	2	2	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	2	201	3	0	2	1	28	5.
Six	0	0	0	0	0	0	1	0	1	0	[illegible]	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	240	0	1	0	14	6.
Seven	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	9	0	0	0	0	0	2	0	231	0	0	18	7.
Eight	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	12	1	3	14	0	192	1	29	8.
Niner	0	0	0	0	0	0	0	0	1	0	0	5	1	16	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	223	12	9.

CONFUSION MATRIX FOR CONDITION LPC 2% ERRORS, ALL SPEAKERS

RESPONSE

Spoken	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	0	1	2	3	4	5	6	7	8	9	NONE	
Alfa	249	0	0	7	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	A.
Bravo	0	254	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	B.
Charlie	0	0	252	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	5	C.
Delta	3	0	0	256	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	D.
Echo	1	0	0	1	242	0	0	2	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	8	E.
Foxtrot	0	0	0	0	0	259	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	F.
Golf	4	0	0	2	0	0	225	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	2	1	1	0	1	19	G.
Hotel	0	0	0	0	0	0	0	254	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	3	H.
India	0	0	0	0	0	0	0	0	245	7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	6	I.
Juliett	0	0	0	0	0	0	0	0	0	258	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	J
Kilo	1	0	0	0	0	0	0	0	0	0	240	0	0	0	0	0	2	0	0	0	0	0	0	0	0	11	5	0	0	0	0	0	0	0	0	0	1	K.
Lima	0	0	0	0	0	0	0	0	1	0	1	247	0	0	0	0	0	0	1	0	0	0	0	0	0	1	5	0	0	0	0	0	0	0	0	0	4	L.
Mike	0	0	0	0	0	0	0	0	0	0	0	0	252	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	5	M.
November	0	0	0	0	0	0	0	1	0	0	0	0	0	256	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	N.
Oscar	0	0	0	0	0	1	0	2	0	0	0	0	0	0	252	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	O.
Papa	[illegible]	0	0	2	0	1	0	0	0	0	0	0	0	0	0	198	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4	P.
Quebec	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	248	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	Q.
Romeo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	259	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	R.
Sierra	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	258	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	S.
Tango	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	247	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	7	T.
Uniform	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	252	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	U.
Victor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	V.
Whiskey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	256	0	0	0	0	0	0	0	0	0	0	0	0	0	2	W.
Xray	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	249	0	1	0	0	0	0	0	0	0	0	0	0	0	X.
Yankee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	257	0	0	0	0	0	0	0	0	0	0	1	6	Y.
Zulu	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	255	0	0	0	0	0	0	0	0	1	0	1	Z
Zero	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	21	235	1	0	0	0	0	0	0	0	0	1	0.
One	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	258	0	0	0	0	0	0	0	0	1	1.
Two	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	256	0	0	0	0	0	0	0	1	2.
Tree	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	247	0	0	0	0	0	0	0	3.
Fower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	0	0	0	4.
Fife	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	258	0	0	0	0	0	5.
Six	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	259	0	0	0	0	6.
Seven	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	7.
Eight	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	247	0	8	8.
Niner	0	0	0	0	0	0	0	0	0	0	0	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	253	2	9.

CONFUSION MATRIX FOR CONDITION LPC 5% ERRORS, ALL SPEAKERS

RESPONSE

Spoken	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	0	1	2	3	4	5	6	7	8	9	NONE	
Alfa	235	1	0	3	0	3	0	1	1	0	2	0	0	0	1	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	A.
Bravo	5	232	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	4	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	13	B.
Charlie	0	0	248	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	3	0	0	7	C.
Delta	28	0	0	225	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	D.
Echo	0	1	0	1	202	0	0	4	0	0	1	0	0	0	0	1	0	0	0	5	1	7	0	0	0	0	0	0	0	0	1	0	1	1	0	0	34	E.
Foxtrot	0	0	0	0	0	258	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	F.
Golf	9	0	1	0	0	0	217	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	1	27	G.
Hotel	0	0	0	1	1	0	0	245	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	10	H.
India	0	0	0	0	0	0	0	0	221	24	1	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	I.
Juliett	0	0	0	0	0	0	1	0	0	256	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	J.
Kilo	0	0	0	1	0	0	0	0	0	2	231	0	0	0	0	0	4	0	0	0	0	0	0	0	0	7	7	0	0	0	0	0	0	0	0	0	8	K.
Lima	0	0	0	0	0	0	0	0	0	0	1	240	0	0	1	0	0	2	0	0	0	1	0	0	0	3	4	0	0	0	0	0	0	0	0	0	8	L.
Mike	0	1	0	0	0	0	0	0	0	0	2	2	215	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	5	1	1	0	6	24	M.
November	0	0	0	0	0	0	0	0	0	1	0	0	0	256	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	N.
Oscar	0	0	0	0	1	4	0	1	0	0	0	0	0	0	238	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	O.
Papa	40	4	0	10	0	0	0	4	0	0	0	0	0	0	1	190	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	P.
Quebec	0	0	1	0	0	0	1	0	0	0	2	0	0	0	0	0	226	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	3	0	0	15	Q.
Romeo	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	R.
Sierra	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	254	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	S.
Tango	0	0	1	0	0	0	0	0	0	0	8	0	1	0	0	0	0	0	0	231	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	15	T.
Uniform	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	255	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	3	U.
Victor	0	0	0	1	0	0	0	2	0	0	1	0	0	1	0	0	0	0	0	0	0	240	0	1	2	0	0	0	0	0	0	0	0	1	0	0	11	V.
Whiskey	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	243	0	2	0	0	0	0	0	0	1	0	0	0	0	10	W.
Xray	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	251	0	0	0	0	0	0	0	0	3	0	0	0	3	X.
Yankee	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	240	0	0	0	0	0	0	0	0	0	0	1	18	Y.
Zulu	0	0	0	0	0	0	0	0	0	1	0	3	0	1	0	0	1	1	0	0	0	1	1	0	0	244	0	1	0	1	0	0	0	0	0	0	5	Z.
Zero	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	1	0	0	0	9	243	0	0	0	1	0	0	0	0	0	3	0.
One	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	1	249	1	0	1	0	0	0	0	0	5	1.
Two	0	0	1	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	3	2	0	0	0	0	0	12	1	0	214	0	0	0	0	11	0	0	10	2.
Tree	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0	0	0	248	0	0	0	0	1	0	6	3.
Fower	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	245	2	0	1	0	0	9	4.
Fife	0	0	0	0	0	4	1	0	0	1	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	233	0	0	1	2	12	5.
Six	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	251	0	0	0	9	6.
Seven	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	1	0	0	0	0	0	254	0	0	2	7.
Eight	0	0	0	0	0	1	0	4	0	0	1	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	9	0	222	0	17	8.
Niner	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	255	3	9.

CONFUSION MATRIX FOR CONDITION LPC 12% ERRORS, ALL SPEAKERS

RESPONSE

Spoken	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	0	1	2	3	4	5	6	7	8	9	NONE	
Alfa	136	3	0	22	0	4	1	0	0	2	0	0	0	0	4	2	0	1	2	2	4	0	0	0	0	0	0	0	0	0	1	2	0	0	0	1	73	A.
Bravo	20	81	2	5	3	1	0	1	0	1	2	3	1	2	1	3	0	8	3	4	2	2	1	0	0	5	1	2	0	0	1	2	0	0	1	0	102	B.
Charlie	2	0	178	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	3	0	0	4	1	7	0	4	2	3	51	C.
Delta	39	0	0	145	0	1	0	0	0	0	0	2	0	0	1	1	0	0	0	2	2	0	0	0	6	2	0	1	1	0	0	1	0	6	0	4	46	D.
Echo	2	1	1	5	83	4	2	4	0	1	0	0	0	1	1	0	0	1	0	6	3	18	0	2	4	0	2	2	1	0	3	0	1	2	0	1	109	E.
Foxtrot	5	0	1	11	0	185	0	0	0	0	0	0	0	0	4	0	0	1	1	0	0	0	1	3	0	0	0	1	0	0	0	1	1	1	0	0	44	F.
Golf	11	3	2	2	1	0	91	1	0	0	2	3	0	0	1	0	1	0	0	1	0	0	0	0	0	2	2	7	1	3	5	1	2	1	1	0	116	G.
Hotel	3	0	1	3	3	2	1	127	0	1	2	2	3	7	2	0	1	2	4	3	0	2	1	2	0	5	1	0	0	0	1	0	0	2	0	1	78	H.
India	0	0	0	1	1	0	0	1	116	22	1	9	0	0	0	0	3	3	3	3	1	0	2	0	6	2	0	0	0	4	0	0	0	1	2	0	79	I.
Juliett	0	0	0	0	0	0	0	0	1	187	0	0	2	0	1	0	3	6	2	0	0	1	0	0	0	2	1	0	0	0	1	1	0	1	0	0	51	J.
Kilo	1	0	0	0	2	0	1	0	0	5	130	5	0	0	0	0	2	0	3	3	1	0	0	0	0	14	26	0	2	0	0	0	1	6	0	1	57	K.
Lima	3	0	0	5	0	0	0	0	3	3	9	167	1	1	0	0	0	3	3	1	0	0	1	1	0	3	5	0	0	0	2	0	0	0	0	2	47	L.
Mike	2	1	1	0	1	0	0	0	1	3	1	3	65	0	2	0	4	4	0	0	0	1	0	2	2	0	0	21	1	2	0	34	0	6	1	14	88	M.
November	5	0	0	3	0	0	0	0	0	2	0	2	1	184	1	0	0	2	2	1	0	0	1	0	0	0	0	2	0	0	0	1	0	1	1	2	49	N.
Oscar	14	0	1	3	0	19	1	2	1	0	0	1	0	0	159	3	0	1	1	0	0	1	2	1	0	0	2	0	0	0	0	2	0	0	0	1	45	O.
Papa	64	2	1	13	0	28	0	7	0	1	0	2	0	1	2	45	2	3	1	1	0	1	0	0	0	2	0	1	0	0	3	2	0	0	0	2	76	P.
Quebec	1	1	0	[illegible]	2	3	0	5	0	4	2	5	1	2	0	0	99	0	1	2	1	4	0	3	2	2	1	2	0	0	0	0	1	10	1	1	101	Q.
Romeo	0	1	4	2	0	0	0	0	2	4	2	6	0	0	0	0	0	172	0	2	1	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	61	R.
Sierra	1	0	0	1	0	3	0	0	0	0	1	3	0	1	0	0	3	0	178	2	0	1	1	0	0	0	19	0	0	1	0	0	0	4	0	0	41	S.
Tango	3	2	0	0	1	3	0	0	3	3	7	4	0	2	0	1	0	2	3	117	2	1	0	0	1	0	1	1	0	0	2	0	4	16	0	1	80	T.
Uniform	1	0	0	1	0	0	0	0	0	3	0	3	0	2	0	0	0	0	1	0	150	0	0	1	7	4	3	2	0	1	0	0	0	1	0	0	80	U.
Victor	0	1	1	1	3	0	0	1	1	1	0	6	2	3	7	0	1	1	1	1	2	164	1	1	0	2	0	0	1	0	0	1	0	1	0	0	56	V.
Whiskey	0	0	0	2	0	4	0	0	1	1	2	1	0	0	2	0	0	0	1	1	0	0	148	4	5	0	1	0	0	0	1	0	2	0	1	0	83	W.
Xray	1	0	0	0	1	15	0	1	2	1	0	1	0	0	0	0	0	0	0	1	3	4	0	153	1	1	0	0	0	0	0	3	3	2	0	0	67	X.
Yankee	0	0	0	2	0	0	0	0	2	0	2	2	0	4	0	0	2	1	3	2	3	0	4	1	129	1	0	3	0	0	0	0	2	1	5	6	85	Y.
Zulu	3	1	1	3	1	0	0	1	3	3	4	3	0	3	0	0	0	1	6	1	4	2	0	0	1	162	4	1	0	1	0	0	0	2	0	1	48	Z.
Zero	1	0	1	0	0	2	0	1	3	4	5	2	1	1	0	0	0	0	23	3	3	0	0	2	0	14	134	0	1	0	0	0	0	4	1	1	53	0.
One	0	0	0	0	0	1	0	1	0	1	0	6	1	3	0	1	1	0	0	1	1	2	2	1	0	3	0	139	2	5	3	2	0	1	1	6	76	1.
Two	3	0	0	1	0	0	0	2	0	0	7	3	0	0	1	0	1	0	1	0	0	0	0	0	0	31	3	1	128	6	0	0	5	6	3	0	58	2.
Tree	1	0	5	0	0	0	0	0	1	3	1	1	1	0	0	0	0	0	1	4	0	0	1	1	0	0	0	1	2	166	0	1	0	1	17	5	47	3.
Fower	0	0	3	1	0	0	1	1	0	1	1	4	0	1	0	0	0	1	3	1	0	0	0	0	1	6	1	3	5	0	149	2	0	6	0	3	66	4.
Fife	3	1	1	0	0	2	0	0	0	0	1	0	21	0	2	0	0	1	0	2	0	0	1	0	0	0	0	2	0	4	0	146	8	1	0	5	59	5.
Six	0	2	0	0	0	1	0	0	0	0	2	1	0	0	0	0	0	0	1	2	0	0	0	1	0	2	1	0	1	2	0	3	204	1	6	0	30	6.
Seven	0	1	0	1	0	0	0	0	1	0	0	3	0	2	1	0	0	1	1	1	0	0	1	0	0	4	1	0	1	0	0	1	1	189	0	2	48	7.
Eight	0	2	1	1	0	1	0	1	1	1	0	10	1	0	0	0	1	1	1	0	3	1	0	0	6	0	0	0	0	5	0	4	31	0	110	1	77	8.
Niner	0	0	1	0	0	0	1	1	0	0	0	11	0	15	0	0	0	8	1	1	0	2	1	0	0	2	0	0	0	0	0	3	0	0	0	149	64	9.

CONFUSION MATRIX FOR CONDITION LPC 5, 8, 12% COMBINED, ALL SPEAKERS

RESPONSE

Spoken	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	0	1	2	3	4	5	6	7	8	9	NONE	
Alfa	595	5	0	39	0	11	1	1	1	2	2	0	1	0	6	4	0	1	2	3	5	0	0	0	0	1	0	1	0	0	2	2	0	0	0	1	94	A.
Bravo	30	526	2	8	3	1	0	1	0	1	4	5	1	2	1	3	0	10	4	9	2	3	2	0	0	5	1	2	0	0	1	2	0	0	1	0	150	B.
Charlie	2	0	645	1	1	0	0	0	0	0	1	0	0	0	0	0	1	3	1	2	0	0	0	2	0	0	4	0	0	5	2	9	0	14	2	6	79	C.
Delta	111	1	0	546	0	2	1	5	0	0	1	2	0	1	1	1	0	0	0	2	2	0	0	0	7	2	0	1	1	0	0	1	0	7	3	4	78	D.
Echo	4	3	2	11	427	6	2	14	0	1	3	3	1	1	1	4	1	1	1	17	5	37	0	3	4	0	3	2	3	0	4	0	3	4	0	1	208	E.
Foxtrot	6	0	1	11	0	697	0	2	0	0	0	0	0	0	4	0	0	2	1	0	0	0	1	3	0	0	0	1	0	0	0	1	3	1	0	0	46	F.
Golf	33	5	6	2	2	0	452	3	0	0	3	7	1	1	1	3	1	5	0	1	0	0	1	0	0	5	4	9	2	4	6	16	2	1	3	1	200	G.
Hotel	3	0	1	4	4	2	2	593	0	1	3	2	3	8	2	1	1	8	4	3	0	2	1	2	0	8	1	0	1	0	1	0	0	3	1	1	114	H.
India	0	0	0	1	1	0	0	1	534	81	3	10	0	0	0	0	3	5	3	4	3	0	2	0	6	6	0	0	0	4	0	0	0	1	2	1	109	I.
Juliett	0	0	0	1	0	0	2	0	4	679	0	1	2	0	2	0	4	8	4	0	0	1	0	0	0	4	1	0	0	1	1	1	0	2	0	0	62	J.
Kilo	1	0	0	1	2	0	1	0	0	7	550	10	0	0	0	0	8	1	4	4	1	1	0	0	0	34	54	0	2	0	1	1	1	12	0	1	83	K.
Lima	3	0	0	5	0	0	0	0	4	3	11	621	1	1	3	0	0	6	3	1	0	2	1	1	1	10	19	1	1	0	3	0	0	0	0	3	76	L.
Mike	2	2	1	0	1	2	0	0	3	4	3	7	446	1	3	0	5	6	0	0	0	1	0	2	3	0	1	24	1	4	0	52	3	8	4	33	158	M.
November	5	0	0	3	0	1	0	0	0	3	0	6	1	665	1	0	3	2	3	1	1	1	1	0	0	0	0	2	1	0	0	1	0	1	1	2	75	N.
Oscar	20	0	1	4	1	40	1	5	1	0	0	1	1	0	613	7	0	1	1	0	0	1	2	1	0	0	2	0	0	0	0	4	0	0	0	1	72	O.
Papa	171	9	1	33	1	38	0	17	0	1	0	2	0	1	4	343	2	3	1	2	0	3	0	0	0	2	0	2	0	0	4	4	0	0	1	2	133	P.
Quebec	5	1	1	3	2	3	1	5	1	4	6	6	1	2	0	1	534	0	3	2	2	4	0	5	2	2	2	3	0	2	0	0	2	22	1	1	151	Q.
Romeo	0	1	4	2	0	1	0	0	2	6	2	7	0	0	0	0	0	668	1	2	1	0	0	0	0	2	0	0	0	0	0	0	2	0	0	1	78	R.
Sierra	1	0	2	1	0	3	0	0	0	0	1	3	0	1	0	0	3	0	672	2	0	1	1	0	0	2	27	0	1	2	0	0	0	4	0	0	53	S.
Tango	3	2	1	2	3	3	1	1	5	8	23	6	1	2	0	1	0	6	4	528	2	1	0	0	1	6	8	1	0	0	2	1	4	19	0	2	133	T.
Uniform	1	1	0	1	0	0	1	0	0	3	0	5	0	2	0	0	1	0	1	1	644	0	1	1	8	4	3	2	1	1	1	0	0	1	0	0	96	U.
Victor	0	1	1	3	3	0	0	4	2	1	1	7	2	5	9	0	1	2	1	1	2	598	2	3	3	6	0	0	1	1	0	1	1	2	0	0	116	V.
Whiskey	0	1	0	2	1	4	0	0	1	1	3	1	0	0	2	0	0	4	1	1	0	1	627	6	8	0	1	0	0	2	1	1	3	0	1	0	107	W
Xray	1	0	0	0	3	17	0	2	2	1	0	1	0	0	0	0	0	0	0	1	3	6	0	639	1	1	0	0	0	0	0	3	8	2	0	0	89	X.
Yankee	0	0	1	3	1	0	0	0	4	0	2	2	0	7	0	0	2	1	4	2	4	0	6	2	582	1	0	4	0	0	0	0	2	1	6	7	136	Y.
Zulu	3	1	2	3	1	0	0	1	3	5	9	13	0	4	0	0	1	6	8	2	6	4	1	0	1	615	14	3	1	2	0	0	0	2	0	1	68	Z.
Zero	1	0	1	0	0	2	0	1	4	6	11	2	1	1	0	0	0	0	38	3	3	1	0	2	0	44	580	0	1	0	1	0	0	8	1	1	67	0.
One	0	0	0	0	0	1	0	1	2	1	0	6	2	6	0	2	1	1	1	1	1	2	3	1	0	7	3	590	3	6	5	4	0	3	1	14	112	1.
Two	3	0	1	1	0	0	0	2	0	4	12	3	0	0	1	0	2	0	4	2	0	0	0	0	0	66	4	2	547	6	0	1	5	19	3	0	92	2.
Tree	1	1	5	0	0	0	0	0	1	3	1	1	1	0	0	0	0	1	2	16	0	0	1	1	0	0	0	1	4	629	0	3	1	1	31	6	69	3.
Fower	0	0	3	1	0	0	2	3	0	1	1	6	0	1	0	1	0	2	3	1	0	0	0	0	1	12	1	3	5	0	627	5	0	7	1	3	90	4.
Fife	3	4	2	0	0	12	3	2	0	1	1	1	31	0	2	0	0	1	0	2	0	0	1	0	0	0	2	4	0	4	2	580	11	1	3	8	99	5.
Six	0	2	0	0	0	1	1	0	1	0	3	1	0	0	0	0	0	0	2	2	0	0	0	1	0	2	1	0	1	2	0	4	695	1	7	0	53	6.
Seven	0	1	0	1	0	0	0	1	1	0	0	3	0	2	1	0	0	1	3	3	0	0	1	0	0	11	1	1	1	0	0	3	1	674	0	2	68	7.
Eight	0	2	1	2	0	2	0	5	1	1	2	11	3	0	0	1	2	2	2	1	3	2	0	0	7	0	0	0	0	17	1	9	54	0	524	2	123	8.
Niner	0	0	1	0	0	0	1	1	1	0	0	16	1	32	0	0	1	9	1	1	0	2	2	0	0	2	0	0	0	0	0	3	0	0	0	627	79	9

CONFUSION MATRIX FOR CONDITION 800 BIT/S PROCESSOR, ALL SPEAKERS

RESPONSE

Spoken	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	0	1	2	3	4	5	6	7	8	9	NONE	
Alfa	251	0	0	4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	A.
Bravo	0	253	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	B.
Charlie	0	0	256	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	C.
Delta	2	0	0	252	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	D.
Echo	0	0	0	4	216	0	1	6	0	0	1	0	0	0	0	0	0	1	0	1	2	10	0	0	0	1	1	0	0	0	0	0	0	1	0	0	15	E.
Foxtrot	0	0	0	0	0	254	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	2	F.
Golf	6	0	1	0	0	0	224	2	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	1	0	0	2	0	0	0	0	0	19	G.
Hotel	1	0	0	1	0	0	0	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	H.
India	0	0	0	0	0	0	0	0	250	6	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	I.
Juliett	0	0	0	0	0	0	0	0	0	256	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	J.
Kilo	0	1	0	0	0	0	0	0	0	0	238	2	0	0	0	1	1	0	0	0	0	0	0	0	0	2	6	1	1	0	0	0	0	0	0	0	7	K.
Lima	0	0	0	0	0	0	0	0	0	0	0	254	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	5	L.
Mike	0	0	0	0	0	0	0	0	1	0	0	0	246	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	1	8	M.
November	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	N.
Oscar	2	0	0	0	1	4	0	1	0	0	0	0	0	0	242	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	O.
Papa	42	0	0	6	1	1	0	0	0	1	0	0	0	0	0	205	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	P.
Quebec	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	238	0	0	8	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	8	Q.
Romeo	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	259	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R.
Sierra	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	253	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	S.
Tango	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	252	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	4	T.
Uniform	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	258	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	U.
Victor	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	254	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4	V.
Whiskey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	255	0	0	0	0	0	0	0	0	0	0	0	0	0	4	W.
Xray	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	256	0	1	0	0	0	0	0	0	0	0	0	0	1	X.
Yankee	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	256	0	0	0	0	0	0	0	0	0	0	1	2	Y.
Zulu	0	0	0	0	0	0	0	0	0	2	2	0	0	1	0	0	0	4	0	1	0	0	0	0	0	237	4	0	3	0	0	0	0	0	0	0	6	Z.
Zero	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	239	0	1	0	0	0	0	0	0	0	0	0.
One	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0	1.
Two	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	2	0	0	0	0	0	0	9	1	0	236	0	0	0	0	0	0	0	9	2.
Tree	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	251	0	0	0	0	0	0	1	3.
Fower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	258	0	0	0	0	0	2	4.
Fife	1	0	0	0	0	7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	244	0	0	1	0	6	5.
Six	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	256	0	0	0	0	6.
Seven	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	0	0	0	7.
Eight	0	1	0	1	0	0	2	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	239	0	12	8.
Niner	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	253	5	9.

END

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